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# The Development of Soviet Railroads

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STAT

# CHAPTER I

## THE DEVELOPMENT OF SOVIET RAILROADS

### INITIATORS OF THE "GREAT BEGINNING"

The railroads in tsarist Russia were constructed at an uneven pace showing spurts and lags. Sometimes unemployment was high among railroad construction workers.

During the years of increasing railroad construction in Russia, the number of railroad workers increased quickly. In 1890, among almost 1½ million workers in large-scale enterprises, there were more than 250,000 railroad workers. Railroad workers were subjected to severe exploitation, and very long ago a revolutionary movement began to develop among them. In the Transcaucasus the revolutionary education of railroad workers -- participants of the first underground organizations of the Bolsheviks -- was directed by I. V. Stalin.

Agitation occurred also among workers engaged in building the Saint Petersburg-Moscow line. In the further history of the revolutionary movement of the working class in Russia, railroad workers invariably emerge as one of its advanced detachments. Railroad workers were in the vanguard of the revolution of 1905-1907. A tremendous role in the events of October 1905 was played by a general railroad strike. The first to strike on 20 October were the workers of the Moscow-Kazan line in Moscow, followed soon by railroad workers of the Moscow junction, and by workers of all the railroads of the country; mail and telegraph services ceased; factories, plants, shops, teaching establishments, and commercial enterprises throughout the entire country went out on strike.

At a congress of railroad workers in November 1905 the question of an armed uprising of the Moscow proletariat was secretly discussed. When the political strike began in Moscow on 7 December, all the railroads except the Nikolayevskaya joined up with it.

The tsarist authorities succeeded in disrupting the strike on the Nikolayevskaya road; workers and employees there were replaced by soldiers of a railroad battalion. Thus the tsarist government was in control of the most important line linking Moscow with Saint Petersburg. Workers' attempts to blow up the bridge in Tver and peasants' attempts to ruin the roadbed near Klin in order to hinder the delivery of government troops were unsuccessful. Then the workers of the Kazan road decided to take Nikolayevskaya away from the enemy.

[Picture on page 302 of text] Comrade Stalin prepares a strike at the main railroad workshops in Tiflis (painting by Artist Khutsishvili

A detachment of armed workers from Kazan endeavored to knock out the troops from the Nikolayevskaya station and to barricade the way to the center of the city. The detachment was armed with rifles found in one of the trains filled with wounded returned from the Far East; it began its advance from the side of the Yaroslavl and Kazan stations, intending to dislodge the troops firmly established in the Nikolayevskaya station. But the Moscow governor-general Dubasov supplied guns to his troops who opened fire upon them. Several of the workers detachment were killed, shells exploded throughout the entire region, and a fire started.

The worker detachment left for the line. Here a revolutionary detachment held out for an entire week thanks to the personal bravery of the workers detachment and to the remarkable skill of the machinists Ukhtomskiy and Akulinin.

Ukhtomskiy and Akulinin drove the train which was placed at the disposal of the worker detachment by the strike committee. The workers detachment carried on operations in Moscow, and then returned to the line in its train; they disarmed the gendarmes and agitated among military units who had returned from Siberia after the Russo-Japanese War. The combat activity of the worker detachment was extremely disquieting to Dubasov; he switched over to the advance, but Ukhtomskiy's train remained elusive.

[Picture on page 303 of text] Machinist Ukhtomskiy

Finally the tsarist government sent to the line a punitive detachment led by Colonel Riman, consisting of six companies of soldiers of the Semenov regiment, armed with machine guns and other weapons.

The line was quickly occupied by the troops. Ukhtomskiy's train was ambushed near Moscow but, thanks to the resourcefulness and skill of this hero-machinist, he broke out of encirclement.



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Ukhtomskiy got the speed up to 90 versts an hour despite the fact that the train was going in reverse; the train broke through machine gun and rifle fire, with the loss of only one comrade from the worker detachment.

The worker detachment was saved but Ukhtomskiy himself died several days later. While riding on horseback past the station of Lyubertsa on 16 December, he stopped off at a tavern; the tsar's secret police happened to be conducting a search there at the time. They recognized Ukhtomskiy by a photograph and seized him and five members of the workers' detachment. Riman gave the order that all should be shot.

Ukhtomskiy behaved like a hero up to the last minute. Even Riman in his report calls him "an eagle". Ukhtomskiy listened to his sentence coolly and only asked permission to write to his wife. The next day, 17 December, the hero-machinist and his comrades were shot near the Lyubertsa cemetery.

The Moscow uprising hardened the workers and trained them as fighters who were victorious twelve years later during the days of the Great October Socialist Revolution.

In the struggle for the victory of the socialist revolution, railroad workers participated most actively under the guidance of the Bolshevik Party. During the counterrevolutionary advance of General Kornilov in August 1917, railroad workers fought in every way against transporting Kornilov's troops. Railroads too were represented in the wave of strikes which arose throughout the entire country against the bourgeois Provisional Government. A general strike of railroad workers took place in September 1917.

In the historic battles for the power of the Soviets in October 1917, armed detachments of railroad workers fought against the troops of the Provisional Government. Railroad revolutionary committees and Red Guard railroad detachments rendered great aid to the Saint Petersburg workers in their victory over the troops of Kerenskiy and General Krasnov.

During the years of civil war and foreign military intervention, railroad transport underwent a more intensive strain to make secure the movements of troops to the numerous fronts in the shortest time and to organize the delivery of supplies and food to the Red Army units. Railroad workers unselfishly performed the tasks which the Soviet authorities placed upon them. Armored trains played a tremendous role on all fronts. Quite frequently, the crews of these "land ironclads" consisted of the men who had built them, i.e., railroad [construction] workers. Especially deserving of merit are the columns of armored trains which operated near Tsaritsyn, the defense of which was led by Comrade Stalin.

[Picture on page 304 of text] Ukhtomskiy steam locomotive

The length of the railroad network in the Soviet Republic during the years of civil war kept changing in accordance with the course of military operations. During the first two months of Soviet authority, practically no changes occurred. Almost the entire railroad inheritance handed down by old Russia and ruined by World War I and by the high-handed management of the tsarist officials was in operation. Then the rebellion of General Kaledin broke out. Military operations against Soviet Russia were undertaken by the "Ukrainian Rada" then headed by Petlyura, and German troops of Wilhelm II began to advance on Saint Petersburg. During the month of January 1918 alone, several thousand locomotives and a considerable part of railroad track was lost. In October 1918 only 20,000 versts of track and 5,000 locomotives remained at the disposal of the Soviet authority.

[Picture on page 305 of text] General railroad strike in 1905 (painted by Artist Savitskiy)

By the end of the civil war, 7,500 locomotives were in working condition with a total track of 53,703 versts, and 11,000 locomotives were awaiting repair.

The reestablishment of the economic life of the young Soviet Republic had to begin with transport. And it is not accidental that it was the railroad workers who laid the foundation for the subbotniks [voluntary work during free time], that "great beginning", as V. I. Lenin called the first Communist subbotnik organized on the Moscow-Kazan road.

The "great beginning" had a tremendous influence upon the establishing of a new, Communist attitude toward labor as a matter of honor. The memory of one such subbotnik is kept alive by the historic locomotive "U-127", the history of which A. T. Kononov relates in his Rasskazy o Lenine [Tales about Lenin] (Detizdat, Moscow, 1938).

"At the Paveletskiy Station in Moscow stands an unusual locomotive. As is proper, it has its own number: U-127.

"But it is recognizable even without a number. It is painted completely red, except the tube which is painted black and the white stripes visible on the wheels. And the name "U-127" is painted in gold letters.

"Every day the dust is wiped from the shining red sides of the locomotive. Recently a glass roof was built over it; now not one drop of rain falls on the "U-127". Here is the story of this locomotive.

"Railroad workers learned that Vladimir Il'ich Lenin used to work during an All-Russian subbotnik in the Kremlin, and they too decided to organize a subbotnik for themselves.

"This subbotnik didn't last just one day. The railroad workers got together many times on their free days and by 1 May had repaired the "U-127" locomotive.

"The locomotive turned out fine: the best blacksmiths and iron workers had repaired it, the best painters had painted it.

"Afterwards the railroad workers decided that they would present the 'U-127' as a gift to the Soviet authority, and that Vladimir Il'ich Lenin would be made an honorary machinist on the locomotive. They decided to send three people to Lenin -- to tell him about this.

"When the three railroad men arrived in the Kremlin, Lenin's secretary told them politely; 'Wait a minute, comrades, Vladimir Il'ich is busy now.'

"But they didn't have to wait. As soon as Lenin found out that the workers had arrived, he himself came out of his office to greet them.

"'Vladimir Il'ich,' the senior member of the workers said to him, 'we have appointed you an honorary machinist on the "U-127" locomotive.'

"He handed Lenin a small book.

"'This is your pay-book.'

"Vladimir Il'ich took the book and read:

Last name, first name, and patronymic: Vladimir Il'Ich Lenin

Job held: Honorary Machinist

"'We repaired this locomotive on a subbotnik,' a worker explained.

"Vladimir Il'ich said, 'Excellent!'

"Then he smiled.

"'You know, I used to ride on a locomotive -- as a fireman. Well, this means that I have a raise now.'

"The railroad workers began to laugh. Each of them knew very well that before the October Revolution Lenin had hidden from his enemies on a locomotive in the guise of a fireman.

"'And this, Vladimir Il'ich, is your pay as a machinist,' a railroad worker declared, and gave Lenin a package with money in it.

"Lenin looked at the package, then at his guests, and was deep in thought for a minute. Then he asked, 'this is my money?'

"'Of course, Vladimir Il'ich!'

"'Well, this is what I want you to do. Of course you have your own club at the station. Send this money there. Let them buy books with it. Or perhaps there's something else you need? You yourselves can see what the club needs most now.'

"The workers looked at one another.

"'How can we do that, Vladimir Il'ich. . .'

"'You just said that this is my money. Well, that means that I can do with it what I want.'

"The railroad workers were silent. Lenin looked at them.

"'Well, what is it that you're in doubt about?'

"The senior worker said, 'Well, among other things, payment will be made every month. . .'

"'Wonderful! Then just send it to the club every month.'

"Then he smiled again and firmly shook the hand of each worker.

"'Recently our railroads have greatly improved their operations. Give your comrade railroad workers my thanks.'

"From that time the 'U-127' did much work on the railroad. It carried passengers and goods. But, most of all, it carried trains with coal for Moscow plants.

"It made its last trip in January 1924. This was the day of heavy national woe: Comrade Lenin had died in Gor'kiy.

"Decorated with funeral flags, the 'U-127' carried to Moscow the body of its honorary machinist."

## THE REESTABLISHMENT OF TRANSPORT

The imperialist war of 1914-1918 led to complete exhaustion of the productive forces of the country, to the disorganization of production, to the utter disintegration of the railroad track and to the catastrophic condition of state finances. The provisional bourgeois-democratic revolution not only did not put a stop to the economic devastation, but contributed to making it more complete.

The final economic collapse and doom of the country was prevented by the Great October Socialist Revolution.

The Bolshevik Party, in saving the country, armed the masses with the idea of a socialist revolution, and organized them in the struggle to overthrow the forces of the bourgeoisie and the landholders. Under the guidance of the Communist Party and its brilliant leaders Lenin and Stalin, the working class of our country in union with the impoverished peasantry completed the Great October Socialist Revolution.

The workers became full masters of the country. The Party called upon them to defend and preserve as the apple of their eye the land, the factories, the plants, and the transportation system which had become national property.

Tsarism and the provisional bourgeois government bequeathed to the working class a land which was utterly ruined by a criminal war, a land robbed clean by foreign and Russian capitalists.

The Soviet authorities took every step to retrieve railroad transport from its catastrophic condition. Railroad workers initiated a revolution in the transportation system. They bore on their shoulders the onus of organizing railroad work.

[Picture on page 308 of text] The first subbotnik on the Kazan' line (from a painting by Artist Epple)

Those were difficult years. Against the Soviet Republic were united the forces of foreign imperialists and of internal counter-revolution. The troops of the interventionists overran our country. It would have been impossible for the young Soviet Republic to stay on its feet without a well-organized railroad transportation system. However, spies and diversionists inflicted blows upon the most sensitive and most important economic nerve of the country -- rail transportation. The Party called upon railroad workers to redouble their revolutionary vigilance.

In order to save the country it was necessary not only to throw units of the Red Army into the front line in time, but also to provide cities and industrial centers of the country with food and fuel. V. I. Lenin demanded that all resources be put at the disposal of transportation. Under the guidance of I. V. Stalin, order was restored on railroads near Tsaritsyn and demolished lines were restored, lines upon which the movement of troops and the provision of food for the workers depended.

It was necessary to introduce the strictest order and discipline in the transportation system. The Institute of Military Commissars was created, and joint responsibility was placed upon railroad employees for delay in traffic and for malicious wrecks.

In answer to the summons of the Party "to work like a revolutionary!" railroad workers organized Communist subbotniks.

By the end of the civil war, the operation of the rail transportation system was extremely difficult. The Party took steps to return skilled cadres to transport duty. The Ninth Congress of the RKP(b) adopted a resolution concerning the mobilizing of 10 percent of the party personnel for transport duty.

Railroad rolling stock proved to be capable of operation only with much difficulty after the civil war.

The locomotive reserve pool had suffered especially. Locomotive "cemeteries" surrounded the station at every junction. During the reconstruction period, the Soviet national economy was confronted with the urgent task of furthering its construction of locomotives built according to its own designs.

It was decided to renew the locomotive reserve pool, and above all to create a Soviet passenger locomotive. The best locomotive left in the old pool was considered to be the locomotive with the wheel formula 1-3-1, series S. It originated in the Sormovo plant in 1911, and was built according to the plans of that plant. Series S thus means "Sormovo."

Series S locomotives were designed for coal heating. Their fire grating had dimensions which were unusual for that time. Thanks to its economy, great tractive power, speed, and convenience in handling, series S locomotives were widely used on Russian railroads. And during the war the Kolomna plant built for the Warsaw-Vienna railroad an improved model of the same locomotive -- the SV. This type of locomotive was used mostly to build up and replenish our passenger reserve pool, and plants were best prepared to build it.

The development of the new type of series S locomotive began chiefly with the changes in boilers. The locomotive had to pull larger trains and was to be fired by poor-quality coal. The number of steam pipes was increased in the new boiler. With the increase in boiler weight, the chain weight of the locomotive was 18 tons on a moving axle. Locomotives of this series were designated Su, which means "strengthened S".

[Picture on page 309 of text] Steam locomotive Series Su

We also rebuilt by a similar method the freight locomotive of the type 0-5-0; series E. At first it was strengthened, then it was modernized, and the freight reserve pool received locomotives of the $E^u$, $E^m$, and $E^r$ types.

[Picture on page 310 or text] Steam locomotive - Series E

The first models of Soviet locomotive construction proved to be the most economical among locomotives of the passenger and freight series.

Of course, of all the requirements for running the railroads, carrying capacity is the most important. However, locomotives can perform well the jobs for which they are designed only if the tracks are in good condition and if adequate cars with tight coupling are available.

During World War I, and later during the civil war, not only did the locomotive reserve pool suffer damage, but this was the case also with cars and tracks. By the beginning of the reconstruction period, the entire railroad trackage of the Soviet Republic comprised 64,000 kilometers. But what a conditions this track was in! The upper structure of the track had not been kept in adequate condition for decades, and stations, shops, depots and artifical structures had gone without repair.

Meanwhile the demand for normal transportation was growing every day, and railroad workers had much work to reconstruct their demolished system.

[Picture on page 311 of text] V. I. Lenin in a railroad car on the way to Petrograd in 1917 (Painting by Artist Vasil'yev)

For the first time in the history of mankind, free man undertook the building of his own national economy. Those forces which previously had been wasted in the severe struggle for existence were now directed to creative labor. And what minds, skill, inventiveness, and persistence were revealed by these people who had been liberated from want and misery! S. T. Grigor'ev -- author and hereditary railroad worker -- has left us his recollections about this creative work in his story "Rzhava-pravaya".

The White Guard ataman, General Shkuro, had burned a station and destroyed a bridge across the Rzhava stream. One end of the far girder had fallen into the water and the other jammed into the first pier. It is said that, as he fled from the advancing Red Army, General Sherigin threw a chervonets [coin equavalent of ten rubles] into the water and said, "It's easier to find a gold coin at the bottom of the river than for the Reds to raise the blasted girder!"

While there have been few who believe the fable about the thrown chervonets, it actually did turn out to be a difficult job to get the girder back into place. However the old railroad technician Ivan Ivanovich Khryashch, aided by workers and neighboring peasants, raised the girder as if without any labor whatsoever. The most important thing remained -- it had to be lowered onto stone piers. Hydraulic jacks were needed but there were none. And so the technician and the young technical director began to ponder ways to lower the girder without jacks. The engineer, who had just been graduated from the institute, was nervous, and bustled about, not knowing what to do. On the other hand, Ivan Ivanovich with ostentatious equanimity picked up his fishing pole and went fishing. Taking advantage of his fishing poles, the boys from the station decided to play a trick on the old man. They sneaked up behind him and dug away the sandy isle on which Khryashch was sitting with his fishing pole, seeing and hearing nothing. The dry sand yielded easily to the children's hands and poured down without a rustle. The hillock gave a tremor and started to creep into the river.

Against his will the old man rescued himself, but understanding what was going on, he suddenly burst out laughing and began to beam with pleasure.

"Then it occurred to me," relates the author, "that while I was transported by some impassioned vision somewhere in the clouds, Ivan Ivanovich, the old realist, was gazing fixedly into the water and sand, thinking how he could find a substitute for the jack. His mind was not on fishing. To me it seemed that he was dreaming or deep in thought. It was the crumbling of the hillock which forcibly roused Ivan Ivanovich and brought that sudden inspiration, that glorious birth of an idea after long and stubborn labor, characteristic of many great minds, according to their statements."

[Picture on page 313 of text] Comrade Stalin at a meeting of railroad workers (painting by Artist I. M. Totsdze)

The old technician, after he had undressed and had dried his clothes, explained the very simple structural plan of a sand jack to his technical director. The line of thinking that had led Ivan Ivanovich to his important invention was such that all he needed was the accident of a child's prank to produce a clear conclusion.

"The water and sand before his eyes had been continuously in his thoughts. He was thinking all the time about what could take the place of the hydraulic jack. In a hydraulic jack, water under pressure raises a piston. If the water is released, the piston descends. We didn't have to raise anything, we just had to lower it. Therefore we didn't need any compression pump. Ivan Ivanovich decided to replace the water in the jack with sand. Water is non-compressible and so is sand. Water flows and so does sand. Water transmits pressure equally and so does sand."

Under the girder, on the pier platforms, the inventors set up sand boxes with frames like wells. The sand was allowed to flow uniformly from the boxes and the girder easily and accurately descended into place. A day later all the operations were completed and that night the first train crossed the bridge.

That which took place at the small unknown station of Rzhavapravaya was repeated at a thousand other stations, large and small. By the creative energy of the Soviet people the Soviet railway system was reestablished in 3-4 years.

The continuous increase in shipment demanded, however, not merely the restoration of transportation, but also its complete reorganization.

During the next 10 years Soviet railroad transportation changed completely. In intensity of operations, our railroad transport occupied first place in the world even before the war.

How could all of this take place and where did the forces and facilities needed for this come from?

We got them not only in the revolutionary inspiration of the railway men themselves, and in the well-thought-out organization of the job, but also in the support rendered to this great work by the entire Soviet people under the guidance of the heroic party of Lenin and Stalin.

## MODERNIZATION OF TRANSPORT

In 1929 the Sixteenth Party Conference adopted the First Stalin Five-Year Plan. The conference made the following appeal to all workers and peasant toilers of the Soviet Union: develop socialist competition for the fulfillment of the Five-Year Plan! The masses rose to the struggle for the fulfillment of the plan.

During the first 2 years of the First Five-Year Plan, there was a significant increase of shipments and passenger travel by rail transportation. In 1930 the railroads of the USSR occupied second place in the world in extent of freight operations, and the freight efficiency of the roads was greater than in the United States.

Despite the progress in transportation, its rate of growth did not keep up with the development of the country's socialist construction. The backwardness of technology, the deterioration of fixed capital, sabotage, major organizational deficiencies in the transportation control system -- all these factors led to a general worsening of transport operations. The party and the government took urgent measures to eliminate these dificiencies.

The Plenum of the Central Committee VKP(b), which took place in Moscow during the summer of 1931, adopted a decision to begin modernization of railroad transportation, to electrify a number of lines with the heaviest passenger and freight traffic, to introduce high-power rolling stock, automatic couplers, automatic brakes, automatic blocking, mechanization of loading and unloading, and at the same time to strengthen the upper structure of the road for locomotives with a large axle load.

The national economic plan is a tremendous job! In capitalist countries, as we have seen, enterprises and inventors for the most part carry out their projects in fear and at their own risk, relying only on their own, frequently false, guess. In those countries, invention, enterprise, and all other creative work is like a game of cards: if you guess the needs of your time, you win; if you don't guess you lose everything -- time, labor, and money!! In our economy the wants and needs of the times are previously introduced into the plan so that each worker knows just what comes first, what is most important. In our country, creative labor is not a gamble; it is the calm, but at the same time enthusiastic, work of the mind and the heart. Its aim is clear and defined.

The first high-power locomotives created were the "Feliks Dzerzhinskiy" and the "Iosif Stalin". These machines were designated the FD and the IS series.

The Luganskiy, now Voroshilovgrad, Steam Locomotive Construction Plant imeni October Revolution began building a new steam locomotive in the same year, 1931, that the decision on the modernization of transportation was adopted.

Neither the planning nor the building came easily. Difficulties lay both in the novelty of the model and in the necessity of resolving a number of technical matters. Here were needed labor, and talent, and faith in one's abilities. But many old specialists didn't have this faith in the possibility of building a new complex machine out of Soviet materials, at a Soviet plant, by the hands of Soviet workers and engineers. But the workers had faith and inspiration to spare. Planning and construction were completed in several months. A delegation of workers from the Luganskiy plant was sent to Moscow for the celebration of the fourteenth anniversary of the October Revolution in a train pulled by the new locomotive.

The first product of our high-power locomotive construction was designated the FD series in honor of the great fighter for the victory of the revolution, Feliks Dzerzhinskiy.

The wheel formula of the FD is 1-5-1.

Steam pressure in the boiler of the locomotive reaches 15 atmospheres. Before entering the cylinders, the steam is superheated. Among additional peculiarities of the design of the FD series must be noted the steel cast cylinders with cast iron bushings. Steel cylinders are more durable than cast iron and at the same time are easier to repair.

An interesting innovation in the series FD locomotive is the stoker, or "mechanical fireman", which automatically feeds coal from the tender into the fire box and distributes it on the fire grate. A fireman could manually stoke the fire box of a high-power FD with only a part of the coal that the locomotive needs for complete steam utilization of the boiler. Moreover, when stoking is done by hand the coal is fed unequally and sometimes incorrectly into the fire box by shovel; the fire box doors have to be opened frequently, letting in the cold which cools the fire box. With a stoker, the fuel is blown by steam through special nozzles; feeding takes place uniformly and continuously, and without opening the fire box doors; the temperature of the fire box, and consequently of steam formation, is not lowered.

The stoker itself consists of a conveyer in the form of an endless screw which resembles a meat-grinder. The screw is located in a trough; as it turns, it breaks up the large pieces of coal into small ones and carries them by a special contrivance which scatters the coal over the fire grate. A separate small steam engine installed on the tender keeps the stoker in operation.

Locomotives of the FD series are imposing in appearance and very handsome as a result of the harmonious relationship of the parts. They are also unusual because of the degree of interior finish. The control booth is well-lighted, spacious, and comfortable.

The contribution of a new type of locomotive for series production did not end the concern for further perfection of the machine. Because we are building our locomotives for ourselves, there is communicated to each person who takes over an assignment some degree of that enthusiasm which results from a personal interest in the entire job.

Members of the Communist Youth League in the Voroshilovgrad plant, for example, in honor of the Tenth Communist Youth Congress painted an FD series ordinary locomotive light blue with white trim and gave it the nickname "Bluebird". The "Bluebird" was entrusted to the delegate to the congress, machinist Petr Krivonos. He did not confine himself to receiving the finished locomotive. No, he arrived at the plant early and suggested that certain of the parts be changed. The directors, engineers, and workers discussed with the exacting master the things that he had proposed and they agreed with him in many respects.

The act of entrusting the "Bluebird" to the machinist and delegate took place at a ceremonial occasion and in the presence of townspeople who had shown up for the celebration.

[Picture on page 316 of text] Steam locomotive - Series FD

Many FD series locomotives are now in use on our roads.

Building up our locomotive reserve pool with freight locomotives of the FD series solved only the first task. A mighty locomotive for heavy passenger trains was also needed. As is known, the carrying capacity of a railroad increases not only by increasing the speed of travel, but also as a result of increasing the number of cars making up the trains.

It was decided to build a new-type passenger locomotive so that it would conform as much as possible with the design of the series FD locomotive. Then it would be easy to mutually replace parts of both locomotives, and to make the majority of them interchangeable.

And so, exactly one year later, by exactly the same procedure, but now at the Kolomna plant, the building of a new locomotive of the type 1-4-2 was completed. It arrived in Moscow for the fifteenth anniversary of the Great October Revolution. This locomotive was designated the IS series - in honor of Iosif Vissarionovich Stalin.

The wheel formula of the IS is different from that of the FD. The IS wheels are considerably larger in diameter. In everything else and in outer appearance and layout, both locomotive are identical.

The IS was intended for passenger trains with a large number of cars -- with a total weight up to 1,000 tons.

With the current demand for fast machines, the speed of the IS was not yet such that Soviet technical opinion could be satisfied with what had already been achieved. Five years later, designers and workers at the Kolomna plant built a fast locomotive of the 2-3-2 type designed for speeds up to 150 kilometers per hour.

In 1940, the Kolomna plant once again released an old $S^u$, water- and air-heated, with its construction perfected. To its series has now been added another letter M, which means modernized. In the modernized $S^{um}$, as a result of the water- and air-heating installation, a decrease in fuel expenditure is achieved. Thus, the short cryptic inscription $S^{um}$ on a locomotive tells us the rather long story of this locomotive.

[Picture on page 317 of text] Stoker

Locomotives of the FD and IS series, like locomotives of the 2-3-2 type and the $S^u$ series, have steam engines which operate with an exhaust, without steam condensation. The coefficient of efficiency for all of them varies between 7 and 8 percent.

Attempts to build locomotive boilers with pressure more than 15-17 atmospheres did not meet with practical success. Compound machines proved to be inconvenient. Nothing can be said about installing a condenser; for a vacuum condenser, a tremendous amount of cooling water would be needed. Moreover, as it is, our locomotives lose much time when taking on water for the boiler.

In these basic flaws of a locomotive -- lack of efficiency and necessity for constantly renewing the water supply -- there would seem to be nothing in common. Actually however we are dealing with two ends of one and the same stick. A locomotive would not expend such a large amount of fuel if it did not have to heat up a lot of water.

[Picture on page 318 of text] Passenger steam locomotive - Series IS

In such a situation, the experience of stationary steam installations with non vacuum condensers could not fail to attract the attention of locomotive builders. By 1930 the first locomotives with condensers had appeared. The purpose of the condensing installation here is still the attempt to obviate the renewal of water supply en route. The continuous circulation of water, leaving the boiler in the form of steam, entering the condenser, and returning to the boiler in the form of hot water, with most insignificant losses along the way, had an effect upon increased efficiency and also upon increasing the operational speed of the locomotive, and made it suitable for operations in arid localities.

A locomotive with a non-vacuum condenser expends 20 times less water and can travel up to 1000 meters without renewing its water supply. The water enters the boiler from the condenser at a temperature of 90 degrees. Superheating the feed water for the boiler, like superheating the air entering the fire box, leads to fuel efficiency.

In a locomotive with steam condensation, just as in a turbine locomotive, exhaust steam is carried off to a condenser, and not to an ordinary cone, which increases the tractive power of the fire box gases. To increase the tractive power, a small turbo-blower is installed in the smoke chamber instead of the cone. The turbo-blower is turned by exhaust steam on its way to the condenser. Ventilator traction improves fuel combustion, as a result of which there is obtained an additional fuel saving of approximately 3 percent.

In addition to all this, the condensation water feeding the boiler is considerably cleaner. Deposits do not form as readily on the walls of the tubes as they do when fresh water is constantly being added, and cleaning tubes of deposits or washing down the boiler is the most frequent type of repair.

[Picture on page 319 of text] Steam locomotive - Series SO

All these advantages of locomotives with condenser-tenders have attracted attention. In 1932 the NKPS equipped one locomotive with a condenser installation.

The new type of locomotive interested Comrade Stalin. The question of series production of locomotives with steam condensation was discussed in his presence. After thoroughly familiarizing himself with the working drawings and after inquiring about all the peculiarities of the locomotive, Comrade Stalin pointed out the necessity of building condensation locomotives as a first priority for the railroads of Central Asia and the Far East and he proposed to grant the Kolomna plant immediately all the necessary funds and materials.

The plant had to equip a new ventilator turbine shop. This is a complicated assembly, which is of strategic importance. Inspiration enabled us to excel past tests; in the very first year the Kolomna plant reequipped more than 100 locomotives.

[Picture on page 320 of text] Steam locomotive - Series CO - with condenser-tender

At the same time the Ordzhonikidzegrad locomotive construction plant contributed a locomotive of a new series which was called the SO -- in honor of Sergo Ordzhonikidze.

It was decided to send one of the first locomotives of the SO series on a long trial run along an itinerary unheard of up to that time, Moscow-Vladivostok-Moscow. It was planned to conduct the tests of the locomotive in time for the October celebrations of 1936.

However the trip had to be postponed. In the People's Commissariat of Communications it was decided to devote this run not for the test of the simple SO locomotive, but to that of the $SO^k$, that is, one supplied with a condenser-tender. The preparations lasted three months. During this time the Ordzhonikidzegrad plant equipped the locomotive SO 17-635 with a condenser-tender for this run.

Machinists tested it and declared that they encountered no difficulties whatsoever: despite a number of new installations, it necessity of building condensation locomotives as a first priority for the railroads of Central Asia and the Far East and he proposed to grant the Kolomna plant immediately all the necessary funds and materials.

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Machinists tested it and declared that they encountered no difficulties whatsoever: despite a number of new installations, it proved to be no more difficult to manage this locomotive than to manage any other of the new series.

And that was the way it had to be. For the $SO^k$ locomotive differed from others chiefly in the tender, on which was placed a steam turbine with a capacity of 150 power and 8000 revolutions per minute. The turbine activates 3 powerful ventilators which create a stream of air for cooling the condenser, consisting of 2610 copper pipes with a total length of more than 5 kilometers. Special plates are fitted onto the pipes -- they increase the cooling area. There are more than 1,500,000 such plates. As it passes the long way through the pipes, the steam is condensed gradually.

The complete circulation of water from the boiler to the condenser and back is completed automatically and does not demand the intervention of the machinist. But of course no automatic device can operate without proper maintenance and attention.

The train left Moscow on its run on the night of 8 and 9 December.

[Picture on page 321 of text] Express passenger steam locomotive, Type 2-3-2, Kolomna Plant

The locomotive left with a train having a weight of 1200 tons. In the trying winter months it crossed the Urals, Siberia, and the Far East twice, sometimes going up to 200 kilometers without stop. The entire trip from Moscow to Vladivostok took 240 traveling hours. After working two weeks in the Far east sector, the $SO^k$ locomotive returned, arriving in moscow on 13 February 1937.

However the existence of such locomotives still does not remove from the agenda the question of motor locomotive traction, although they are very convenient in places which are not provided with water. The diesel remains nevertheless an engine which is unsurpassed in efficiency. True, it needs more expensive fuel -- petroleum -- but it happens that we have lines passing through waterless localities which are nearer petroleum than coal. Consequently the appearance of locomotives with condenser-tenders has by no means put an end to the transition to motor locomotive traction for lines affected by the decision of the Central Committee of the party.

As early as 1924 our first high-power locomotive with electric transmission was built at the Kolomna plant. It was built, as has already been said, simultaneously with those ordered abroad. The diesel motor with a capacity of 740 horsepower operated on a generator of electric current, and the electric motors -- one apiece for each moving axle -- activated the wheels.

The first Soviet motor locomotive turned out not to be powerful enough and did not provide an engine of sufficient speed. It was not suitable for series production and the People's Commissariat of heavy Industry designed working drawings, first, for a series $E^{el}$ locomotive with a capacity of 1000 horsepower, and, subsequently, for a locomotive with a capacity doubled to 2000 horsepower.

In honor of V. M. Molotov this locomotive was called the VM series. It was built entirely of Soviet materials and by Soviet engineers. Thus, electric transmission decided the problem of utilizing a diesel motor for traction.

The ideas and experiments of Soviet locomotive builders, reviving interest in motor traction, were widely used in Europe and the United States of America.

Meanwhile electric transmission in no way represents better or perfect utilization of a diesel on a traction machine.

Every transmission takes away from an engine a certain part of its capacity, expending it for friction of transmission parts of the mechanism, but electric transmission in addition considerably complicates the design, it still more increases the cost of the locomotive, and it hampers its operation. And it is completely understandable that designers continue to seek new ways of uniting in a locomotive the merits of a diesel and of a steam engine, at the same time eliminating the deficiencies inherent in them.

Therefore still greater interest is being shown in direct action locomotives.

The basic deficiencies of a diesel, as we have already seen, lie in the fact that its rate of speed cannot be changed suddenly. A diesel making, say 200 revolutions per minute will not start to operate at less than 100 revolutions. Further slowing down of piston rate leads to slow air compression and the temperature in the cylinder proves to be insufficient for the spontaneous combustion of the fuel. Moreover, the efficiency of the engine is lowered too, because its efficiency lies precisely in high compression.

It is also impossible to raise the capacity of a diesel by increasing the input of fuel; the cylinder absorbs a strictly limited amount of air and only a limited amount of fuel can be ignited in it.



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The apparent hopelessness of the situation impels the specialists to search for all sorts of transmissions. Builders of locomotives look upon the design of a diesel simply as something inviolable and make no attempt to change anything in it.

The Soviet inventor and designer Mikhail Ivanovich Prigorovskiy took another view of the matter. As a student, he worked with a designer of heavy airplanes and made a complete study of the operation of powerful gasoline engines. He was familiar with the diesels designed by professor Kositskiy -- one of the first theoreticians and historians of diesel construction. After finishing the Kiev Railroad Technical School, Prigorovskiy worked as a repair worker, a fitter, and a machinist. Thus Prigorovskiy knew both locomotives and engines as well as he knew his five fingers. At one time he got the idea of rebuilding a diesel so that, in addition to its own qualities, it would also have the excellent qualities of a steam engine. Wherein did they lie?

[Picture on page 323 of text] M. I. Prigorovskiy

Answering this question for himself, Prigorovskiy took a somewhat unusual but completely correct and, above all, a very clear point of view. He reasoned as follows: a steam boiler with a fire box is a generator, that is, a producer of steam. In the fire box of the boiler, fuel is burned and converts water into expansible and hot steam. Fuel combustion and steam formation proceed continuously and persistently. Steam -- now converted into power under control -- enters the cylinder in a greater or lesser amount. Therefore within very wide limits it is possible to regulate the rotation force of the moving axles. All these very valuable qualities of the steam engine lie in the fact that it is a receiver of controlled power.

A diesel needs energy from within only when it is started; thereafter it can produce energy itself -- the gases which expand when the fuel is burned. To give a diesel the properties of a steam engine, it should not have a device to ignite the fuel when the capacity is lowered and it should have less air, necessary to burn the fuel, when it is increased. Prigorovskiy decided to compensate for these shortages in a traction engine.

Prigorovskiy proposed to install in the traction engine a compression assembly, an "air generator" so to speak, providing compressed air for the traction diesel. This installation was to have its own auxiliary diesel, and it was to supply with energy and ignition device for the traction diesel.

In Prigorovskiy's plan, apart from the normal intake of air, the cylinder of the traction diesel was to receive an additional charge of compressed air mixed with fuel whenever greater engine capacity was needed. The air and fuel input here was like the steam cutoff in a steam engine and leads to the same results; it makes it possible within very wide limits to regulate the rotation of the moving axles. A link gear for distributing compressed air and for feeding fuel makes handling a motor locomotive no more difficult or complicated than handling a steam engine.

The putting into practice of this simple and refined engine can begin a new chapter in the history of locomotive construction.

The type of locomotive with electric transmission most widely used today is nothing else than an electric locomotive with a diesel engine.

To deliver a current to an electric locomotive from a rayon hydroelectric station or electric station operating on cheap fuel, is of course more profitable than installing on it its own station with a turbine or diesel. However, aerial line is very expensive and, most important, requires large expenditures of metal.

Which then of the two types of electric traction is the better? Here everything depends upon local conditions.

We are building high-power rayon hydroelectric stations and electric stations operating on local cheap fuel. Electric power in such an instance costs less and it is more profitable and convenient for us to carry current to the railroads along aerial lines from these stations. And where there are no rayon electric stations yielding cheap current, such as in the steppes and deserts of Central Asia, we have locomotives operating.

As early as 1935 we had electrified 1207 kilometers of track and had 84 electric locomotives in operation. Since that time these figures have considerably increased. Just like ordinary locomotives, electric locomotives are serviced like freight traffic and like long distance passenger traffic; suburban communication is effected by trains consisting of motor and trailer cars.

The series of electric locomotives for freight traffic was given the initials of V. I. Lenin -- V.L. A high-power, high-speed electric locomotive, designed for long distance, fast passenger trains, bears the letters PB in honor of the Politbyuro TsK VKP(b).

[Picture on page 324 of text] Electrified sector of suburban railroad line

The striving for super high-speed railroad transport has given rise in recent years to still another means of transportation -- railway motor cars. These are cars equipped with a motor which by some method is connected with the moving axles. For the most part, the same power installation is used as on locomotives with electric transmission.

An idea of this new type of railroad transportation is given by the Soviet high-speed railway motor car built in 1936 by the Kaluga Machine-Building Plant. It was intended for suburban communication and consists of 2 cars of a streamlined form and all-welded construction. There are 87 places in the trailing car and 58 in the motor. All seats are upholstered. The interior finish of the car is marked by its refinement and comfort.

In the front part of the electric motor car are situated the machine section and the controls. The power installation consists of a diesel motor with a capacity of 440 horsepower, a 250-kilowatt generator, and 2 traction electric motors. A railway motor car is thus a locomotive situated in the same car with the electric transmission.

[Picture on page 325 of text] Electric passenger locomotive PB

The Soviet motor car is designed for a speed of 115 kilometers



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per hour. It can travel the distance between Moscow and Leningrad in 6 hours, when our best rapid trains ordinarily take no less than 9 hours to cover the same distance.

Our locomotive reserve pool includes a whole series of engines which are excellent and perfect with regard to modern conditions of technology. But science and technology do not stand still, and the new generation of designers and engineers will not have to sit idle.

Natural conditions are very diverse in our country. In individual sectors of the railroad network, use of one or another locomotive proves to be more profitable. In the process of struggling for preeminence, technical specialists are perfecting and proposing various types of traction engines. It is fruitless at this time to foretell the preeminence of one or another type of locomotive. In our time of grandiose discoveries and inventions, it is always necessary to be ready for an engine to appear tomorrow, an engine which is completely unlike any now existing, and which solves the problem of traction in a completely new way.

Together with the locomotive reserve pool, the railroad car reserve pool was reorganized. For heavy trains, heavy-load freight cars with firm coupling and automatic brakes are needed. At the same time, passengers demand from socialist transportation not only speed and safety but also comfort.

Of course, it is impossible completely to replace old freight and passenger cars with new ones in a few years. We still have on our roads the 2-axle small cars which at one time bore the humorous inscription "40 horses and 8 men." However, our railroad car reserve pool is being supplemented more and more by remarkable finished products of the Ural, Kryukovo, and other railroad car building plants.

Plants are building for our roads heavy-load covered freight cars; half-cars, or as they are sometimes called, gondolas; tank cars; and flat cars. The carrying capacity of gondolas is 60 tons. These and others are 4-axled, equipped with automatic coupling and automatic brakes.

[Picture on page 326 of text] Hopper

The railroad car reserve pool is also being augmented by a whole series of specialized cars. Among these are hoppers -- self-unloading cars for hauling coal, ore and similar freights -- and specialized tank cars for hauling various acids. Refrigerator cars are also being perfected more and more; in these cars a special temperature is maintained for each kind of freight.

During recent years the railroad car reserve pool has been considerably replenished, but the demands on our growing network are so great that to satisfy them completely and to replace the old cars with new ones will require more time, and, most important, the intensified and well organized operations of the railroad car construction plants.

[Picture on page 327 of text (top)] Tank car

Our railroad car construction plants have begun the construction of rigid, all-metal passenger cars with improved interior finish.

We are continuing to improve cars newly released.

Kazakhstan can give an idea of the development of railroad communications in the Soviet Union. Prior to the Great October Socialist Revolution, there were almost no railroads there. During the Soviet era, on the other hand, more roads were built in this country than in any other part of the Union. In 1927-1930 the Turkestan-Siberian trunk line, having a length of 1442 kilometers, was installed. In the next year there began the construction of the road from Petropavlovsk to Karaganda, and in 1936 one from Karaganda farther on to Balkhash, for a distance of 482 kilometers. In subsequent years the Gur'ev-Kandagach line (550 kilometers) and the Ural'sk-Iletsk line (263 kilometers) were installed. Finally, at the end of 1940 the first train traveled along the Akmolinsk-Kartaly line for a distance of 806 kilometers.

[Picture on page 327 of text (bottom)] Refrigerator car

That is how the railroad network of the Soviet Union is growing everywhere.

On 15 May 1935 still another railroad, completely unique in its characteristics, entered our railroad economy -- the Moscow subway imeni L. M. Kaganovich.

E N D

## COUPLED LOCOMOTIVES AND COMPOUND LOCOMOTIVES

The tractive force of a locomotive depends on the one hand upon its coupling weight, and on the other hand upon the capacity of the engine itself.

The engine capacity, in its turn, depends upon the amount of steam pressure in the boiler. However, steam pressure even in the latest locomotives does not exceed 15-18 atmospheres. The problem is not completely one of limited durability of materials which can withstand these higher pressures. No, the basic difficulty lies in maintaining this pressure at a constant level.

As steam is expanded by the engine, the boiler pressure in the boiler, naturally, falls. It follows that a boiler must possess an efficiency which would immediately replace the loss of steam.

The Cherepanov locomotive was successful precisely because the inventors increased the heating area in the new boiler and thus achieved steam efficiency which was high for those times.

We should mention, by the way, that the heating area in modern locomotives is as much as 500 square meters, and such a sharp increase of boiler capacity, let us repeat, is achieved without changing railroad gauges!

Increasing heating surface, the designers at the same time were, of course, also working to improve boiler proportions: they were expanding fire box dimensions and dimensions of the boiler itself, although railroad gauges limit their height, width, and length, and the upper structure of the tracks establishes limits for the coupling weight of the locomotive and axle load.

The modern locomotive has reached a stage that it has almost lost the smokestack. Traction is achieved in the fire box by installing a cone, the improvement of which is the constant concern of designers.

The growth of locomotives in length is also limited: if you lengthen the boiler, then naturally you must also increase the extent of the chassis section to place the boiler on it. But up to a certain point, such a locomotive can no longer travel freely around curves on tracks intended for other gauges. This state of affairs also confronted designers when laying track around sharp curves. Engineers extricated themselves from the situation by using turning trucks on which the ends of the chassis frame lie freely, so that, upon approaching curves, the trucks make the turns independently, while the frame, while rounding the curve, turns by means of moving axles on which it rests immobile.

But the problem is not just in the boiler dimensions. When its dimensions have been increased many times, inevitably the total weight of the locomotive increases, and its weight cannot exceed that permitted by the durability of the tracks.

[Picture on page 187 of text] First tank-steam locomotive from Kolomna Plant; good view of coupling link.

That means that in order not to exceed the maximum axle load for a given track, it is necessary to increase the number of locomotive axles. And if the total weight of the locomotive cannot be distributed between the moving axles capable of rounding curves freely, then the designers have no alternative but to add supporting axles in front or in back, as required. Those in front have received the expressive name "runners".

Thus, technology has approached the raising of total steam efficiency of locomotives and their boiler capacity by two routes: on the one hand, retaining the coupling weight and the boiler proportions of the locomotives, they have added runners making it possible to use a boiler with the larger heating surface; on the other hand, without changing the locomotive type, they have improved the boiler proportions and increased smokestack and fire box dimensions.

Speed and tractive force are to a considerable degree determined by the number of moving wheels.

[Picture on page 188 of text] Skam locomotive with double boiler.

Having one and the same piston rate and force upon it, a locomotive with large wheels will develop high speed and low traction, and with small wheels will develop lower speed, but higher tractive force. In either case, the wheel makes one turn in the same amount of time, but the larger one travels a greater distance than the small one, and that means that in the same length of time the locomotive will move farther. That is why passenger locomotives have larger wheels -- up to 2 or more meters in diameter -- while the wheels of freight locomotives never exceed $1\frac{1}{2}$ meters.

At first, attempts were made to put wheels of tremendous dimensions on express locomotives, but it turned out that this lowered the tractive force very much.

In order to move the train from a full stop, a locomotive must have a good grip upon the rails. If for some reason the rails become slippery, it is necessary to increase traction by sprinkling sand under the wheels; locomotives are supplied with sand boxes for this purpose.

According to one of the basic laws of friction its force is directly proportional to the pressure of one surface upon another. For that very reason it is profitable for a locomotive to have as great a coupling weight as possible. Because with one pair of moving wheels there is transmitted only a part of the total weight of the locomotive, traction of 1 pair of wheels upon the rails is nevertheless insufficient. Therefore, it is necessary to join together 2 or even more pairs of moving axles by means of coupling connecting rods. In such a case the piston causes all the paired wheels to turn, and thus the total force of their coupling is utilized.

In the final analysis the number of axles best characterizes the type of locomotive. Therefore, in order to characterize a locomotive, there is used a number formula made up of 3 digits, where the middle figure means the number of moving axles and the outer figures mean the number of supporting axles located in front and in back. The wheel formula 1-5-a, for example, means that the given locomotive has 5 moving axles, 1 runner in front, and 2 supporting axles in the rear.

Limited on the one hand by gauge and on the other hand by maximum axle load, designers did not sit idle but started to seek a way out in another direction. Engineer Ferli built a locomotive with 2 separate boilers which were joined back to back. Each boiler had its own combustion chamber, armature, and smokestack, but there was a common fire box with 2 combustion chamber doors. The wheels of the doubled locomotive were fastened onto short turning trucks so that, despite the long boiler, it would be easy to round a curve.

Faced with an installation in which the boiler remains fixed while the steam cylinders change their position with relation to it during turns, Ferli had to resort to moveable steam pipes from the boiler to the cylinders. He equipped the steam pipes with moveable elbows, which of course had an effect upon the total durability and simplicity of the installation.

Ferli's locomotive had one irreplaceable convenience that it did not have to be turned around because smokestacks were located at both ends of it.

Ferli built his locomotive for the mountain Zemmeringskaya Railroad and later on it was found suitable for roads with steep slopes. Ferli's locomotives used to operate also in Mexico, Peru, and in the Sura pass of the Transcaucasus road.

Now they are used as tank locomotives. That is what locomotives without a coupled tender are called. Water and fuel supplies are of course located in limited quantities on them, in special containers, or tanks, either on the boiler, or alongside it, or under it. Because the tender is missing, tank locomotives are in general very convenient for switching operations and for operations on industrial sidings.

[Picture on page 189 of text] "Two-headed" steam locomotive.

A powerful locomotive, as has already been pointed out, must be very long because it needs a large amount of steam and, moreover, the axle load must be distributed correctly. Turning trucks could no longer save the day, and accordingly American designers undertook the construction of coupled locomotives which were called mallets, after the Swiss engineer Mallet, who had proposed such a locomotive in 1887.

Coupled locomotives have 2 steam engines, but only 1 boiler; One engine is located on the same frame as the boiler and the other is located on a special frame. The second is joined to the first by means of a swivel pin and the frame turns independently of the first when going around curves. The result thus is that the entire front group of moving axles becomes a tremendous turning truck, while the rear group remains immobile around curves.

Among the shortcomings of coupled locomotives one must mention their cumbersomeness, the extreme complexity of their repair, and their low speed. Unable to supplant the current freight locomotives with respect to speed and efficiency, coupled locomotives did not at first find wide application. Series construction of them did not even begin, and experimental construction was stopped.

The development of coupled locomotives and their practical application, as we shall see later, began only after the Russian engineer A. P. Borodin carried out successful research of a "compound" system, and another Russian engineer, Ye. Ye. Nol'teyn, improved the design of the "receiver", a special installation providing for starting a compound system coupled locomotive from rest, because with a system of compounds, a coupled locomotive without this additional installation does not possess the capacity necessary to start the train from rest.

[Picture on page 190 of text] Russian coupled "Fita" steam locomotive.

The aim of designing a coupled locomotive was, first, to facilitate a powerful locomotive's travel around curves and, second, to distribute the weight in the best possible manner. In addition to this system, there also exist other designs of coupled locomotives which have a different placement of the engines.

Pairing of wheels is the basic principle in locomotive construction, resulting from the laws of friction. The same laws suggest to designers to transfer to the paired wheels as large a load as is possible. By combining the number and dimensions of paired wheels in a certain way, the designer arrives at a solution of his problem.

The coupling of locomotives represents one of these solutions as it makes possible the placement of a sufficiently large boiler on the rails without changing the tracks and without extending beyond the limits of the gauge.

The narrow gauge of locomotives have given rise to no small number of obstacles in the way of increasing steam tractive capacity, but they do not stump the creative ingenuity of the designers.

Russian technical thought has nearly always been the first to respond to the successes in locomotive building.

The Putilovo and Kolomna plants were the first to construct coupled locomotives.

[Picture on page 192 oftext] Steam cylinders of compound machine for doubled steam expansion: right-high pressure cylinder, left - low pressure cylinder.

Russian coupled locomotives were given a series indicated by the letter F, which was removed from the Russian alphabet after the revolution; in contrast to the ordinary F, it was then called "fita". The wheel formula of our "mallets" was 0-3-0+0-3-0. They first appeared on the roads in 1897 and operated sufficiently well.

Several years later the Kolomna plant released a new series of coupled locomotives of the type 1-2-0+0-2-0, which were lighter. They were designed for servicing passenger trains on difficult mountainous sectors of the Siberian modern Russian alphabet, the letter I.

The modern locomotive has by no means been brought to the final stage of perfection. In no way can it be said that the new generation of inventors and designers has nothing to do in this field!

The coefficient of efficiency does not exceed 8 percent in a modern locomotive.

Of each 100 kilograms of coal fed into the fire box, only

7-8 percent of it is expended with direct advantage. And because in the Soviet Union approximately one-third of the entire extraction of coal is consumed by railroad transportation, it is easy to understand what significance even the smallest increase in the efficiency of our locomotives can have!

The efficiency of a steam engine is significantly increased by using repeated steam expansion.

Heat loss takes place in a considerable amount when we introduce into a cylinder high-pressure steam which cools off all by itself even before it reaches the atmosphere or the condensor.

The situation can be improved if too great expansion does not take place in the cylinder; then the temperature changes will be smaller.

In order not to lose energy, it is necessary, after allowing the steam to expand somewhat in one cylinder, to carry it then to another, and to carry out further expansion here.

In engines that use repeated steam expansion, the so-called "compound engines", the steam enters the boiler in a smaller high-pressure cylinder, and from there, expanding gradually, is carried to medium- and low-pressure cylinders, where its work is ended. Each cylinder has its own steam distribution.

These complicated compound engines of doubled, tripled, and quadrupled steam expansion proved to be quite profitable and were widely used as stationary and ship engines. The coefficient of efficiency in them reached 10 percent, and sometimes even more. Then compound locomotives appeared with doubled steam expansion.

High-pressure cylinders in these locomotives were placed towards the rear, and the low-pressure cylinder towards the front.

However, it soon became clear that the application of doubled steam expansion was not yielding the same good results in the locomotive as in stationary or ship engines with condensors. Although in general a certain saving of fuel does take place, it does not warrant the major inconveniences in handling the engine or the complications of repairing it. Compound locomotives were built generally at the end of the last century and the beginning of the present one. Now, however, they have disappeared almost everywhere. The compound system proved to be unsuitable for a locomotive engine, which needs, first of all, relative simplicity of installation, durability, and ease in control, maintenance, and repair.

A transport steam engine must satisfy difficult conditions; it must withstand jolts and shaking; it must operate sometimes at full capacity and at other times reduce it to the minimum. Frequent starts and stops have a telling effect upon the mechanism. Only the bottom resting on the rails and being free everywhere else, a locomotive is subject, as a result of the action of force of inertia, to the most diverse, harmful vibrations. On curves of the track it pushes out or "undoes" the rails. Ordinarily a locomotive is subjected to continuous inspection under unfavorable conditions, and, therefore, all its critical parts must be accessible to the eye.

All this taken together deprives a transport steam engine of the possibility of profiting by the many achievements of steam technology, and the basic type of locomotive to this day is chiefly the 2-cylinder simple-action engine with a valve for the exhaust steam to atmosphere.

A great achievement of steam technology, suitable for perfecting the locomotive, proved to be the superheating of steam.

It should be stated, by the way, that the introduction of superheated steam to a great degree was a contributing factor in railroad technology's rejection of compound locomotives.

The superheating of steam, like its repeated expansion, increases the coefficient of efficiency of the steam engine, but in no way complicates handling the locomotive or its design.

Stationary steam engines use both methods for increasing efficiency both superheating and repeated expansion. But locomotive building in our day relies chiefly on superheating for this purpose.

In modern locomotives, the steam from the steam collector of the steam dome installed in the boiler passes through a special superheating device before it enters the cylinder.

This device consists of long tubes laid out in the form of coils situated in the upper, so-called "heating", tubes of the boiler; the tubes, therefore, have a larger diameter than fire tubes. Fire box gases, passing through the heating tubes heat the steam superheater. Steam which enters it from the boiler is moist, that is, it carries with it small particles of water, but it leaves the superheater very dry and at a high temperature.

Wherein lies the significance of superheated steam?

Throughout the course of the entire history of the steam engine, designers and inventors have striven to increase its efficiency by three methods: by increasing steam pressure, by utilizing its expansion, and by eliminating condensation in the cylinder.

Carefully raising the pressure and boldly utilizing steam expansion, they also counteracted steam condensation in the cylinder. To heat the cylinder, a second, outside casing is used; this covers the inner steam cylinder. Between the two of them there remains some space which is filled with steam. This steam sheathing is present in all modern steam engines, and its function lies in eliminating as much as possible the cooling of the cylinder walls, and also in hindering steam cooling and condensation in the working cylinder.

[Picture on page 193 of text] Compound steam locomotive - Series N

It is well known that the steam from the boiler does not emerge dry, in a gaseous state, but moist and saturated with fine particles of water. A certain cooling of the steam as it enters the cylinder and in the cylinder itself cannot be eliminated. And it is this saturated steam which condenses quickly upon entering the cylinder that, of course, greatly lowers the coefficient of efficiency of the engine.

If, however, before it enters the cylinder, the steam is heated at a constant pressure equal to the pressure of the saturated steam, a fluid substance possessing all the properties of a gas is derived. Whenever the temperature of this superheated steam is lowered, it simply decreases in volume, but it does not liquefy; however, the walls of the cylinder can absorb heat only within small limits, otherwise the superheated steam will lose its properties. It is necessary, therefore, that the temperature of the superheating be kept at a level no lower than 300-350 degrees.

Superheating, by eliminating condensation in the cylinder, raises the percentage of utilization of heat derived from the burning of fuel.

[Picture on page 194 of text] Four-cylinder compound steam locomotive, Passenger type, from Putilov Plant

As a result of the very great fluidity of superheated steam and its easier passage into the cylinder, steam pressure losses caused by friction of particles of it in the steam pipe are significantly reduced.

Moreover, the volume of superheated steam at a level pressure is greater than with the same amount of saturated steam. Piston operation in the cylinder depends upon the volume of steam entering it and upon its pressure. And since the volume of superheated steam is increased, that means that it is possible to decrease its pressure in the cylinder and to a certain degree in the boiler; this again raises the locomotive's coefficient of efficiency.

Thus, the application of superheated steam is proving to be very profitable; it eliminates initial condensation of steam in the cylinder, which even a compound system could not achieve; it makes it possible to lower the pressure limit in the boiler without lowering the coefficient of efficiency to, say, 12 atmospheres instead of the 15 atmospheres ordinarily standard in compound engines.

Superheating of steam proved to be so convenient and profitable for locomotives that as early as 1909 more than 3,700 locomotives equipped with steam superheaters were in use in Europe and America. In the entire history of railroads, no other single invention has been widely incorporated in locomotive building with such rapidity and energy. In our country, as well as abroad, compound locomotives which had not justified themselves in operations gradually started to be converted and their design was adapted to the application of superheating.

The first compound locomotives for passenger traffic, of the type 2-3-0, was built at the Kolomna plant from 1892 on under the series designation A. At first the series $A^d$ appeared. Later all of them were converted and supplied with superheaters. A new series resulted: $A^p$.

It is not difficult to see that the letter designation of the locomotive series to a certain degree tells a person devoted to his job the history of the given locomotive design.

At the present time, series $A^p$ locomotives, being obsolete and low-power, operate on less important sectors, and are frequently used for all sorts of secondary operations.

[Picture on page 195 of text] Freight locomotive, Series E, with superheated steam

Among the compound systems belong also the series G locomotives built in 1900 in the Bryansk plant. They were distinguishable not only by the complexity of design, like all compound locomotives in general, but also they surpassed the planned weight, for which reason they were used on a limited scale. In the course of the next decade they were all converted into simple locomotives with superheated steam. These are called the G series.

The U series locomotives, of the 2-3-0 type with a 4-cylinder compound engine, are very interesting. They received a good reputation, being distinguished by smooth motion at high speeds, but their boilers did not produce enough steam. They were redesigned in 1912. Superheaters were installed on U locomotives, the cylinders were intensified, and the fire grate was expanded. The resulting series was U -- that is, series U, intensified. These locomotives operated for a long time on the Ryazan'-Uralsk Railroad.

Series Ch, Sh, and Shch also had a compound engine. Of these, locomotives of the last series were the most widely used. They were designated by the first letter of the last name of the designer, Shchukin, and are sometimes encountered on our roads even now.

The application of superheated steam must be considered the most important improvement of the locomotive. The saving derived from superheating steam comes to approximately 20 percent in lowering steam expenditure, and 15 percent for fuel expenditures.

Preliminary heating of water fed into the boiler by exhaust steam, and heating of air entering the fire box and heated by fire box gases also result in considerable savings. These means in the struggle for efficiency in traction did not come to be resorted to until recently, but they are becoming more and more frequent.

E N D